PROMOTING EARLY MATURITY IN TOMATOES BY BREEDING AND CERTAIN CULTURAL PRACTICES

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A THESIS

submitted to the University of Alberta

to fulfill approximately one-half the requirements

for the degree of

MASTER OF SCIENCE

Edmonton, Alberta

March, 1942.

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INTRODUCTION

Successful tomato culture under Alberta conditions requires that the plants set and ripen their fruits quickly. In warm, long frost-free seasons good yields of high quality fruit are generally obtained in the province, but during cool, wet seasons tomato plants grow slowly with the result that yields are small and discouraging. In short, frost-free seasons also, tomatoes lack in time to ripen their fruit and in many cases green fruit only is obtained. There is a definite need in Alberta for varieties which are capable of not only ripening fruit early in the season but of doing so consistently each year. Also, certain cultural practices which are not as yet widely used, could become useful aids in promoting early maturity in tomatoes.

Much has been accomplished in recent years in developing tomato varieties and methods of culture for early fruit maturity. One case deserves special mention, namely, the origination of the Farthest North variety which is the earliest tomato in commercial seed channels. By the use of this variety home

gardeners have been able to grow ripe tomatoes outdoors as far north as Peace River and Fort Vermilion. The Farthest North is extremely early, in fact so much so that in favorable years it ripens large quantities of ripe fruit even when seeded outdoors. Unfortunately the economic possibilities of the fruit of the Farthest North are limited since these are small and measure at best 1 to $1\frac{1}{4}$ inches in diameter.

Early ripening processes.

The ripening processes in tomatoes consist essentially of a number of chemical changes together with the building up of dry matter in the plant. The sooner these processes take place the more rapid will ripe fruit be produced. MacGillivray (37) stated that "the ripening process seems to include a change of carbohydrates of high molecular weight to sugars, an increase in dry and fresh weight, an enlargement of practically all cells, and the disintegration of the cell walls".

Since the object of this thesis investigation is not concerned with a technical discussion of the processes of ripening, the present knowledge of the complex chemical changes that take place is not reviewed. However, Sando (47) has provided a good reference for information on the subject.

Effects of certain environmental and cultural practices on early ripening.

The environment generally has a profound effect on the

development of the tomato in the field. If the temperatures are comparatively high the plants grow rapidly and the fruit sets abundantly. On the other hand, if the weather turns cold, the effects are often harmful and also may be disastrous.

A sandy soil is possibly one of the greatest contributing factors to successful tomato culture because of the rapidity with which it warms up and because it has a higher temperature than most other adjacent soil types. No doubt the sandy loam soil at Taber is largely responsible for the fact that tomatoes ripen roughly a week earlier there than at Lethbridge. The soil at Lethbridge is a heavy loam.

Smith (51) and Smith and Cochran (52) reported that fruit setting did not occur if the temperature was above 100° F. or below 50° F. Optimum fertilization and fruit setting occurred at temperatures of 70 to 85° F. According to this information the set of early fruit would be inhibited by cool or hot weather when the plants begin to blossom. Conditions such as these occur in certain seasons in most parts of Alberta and no doubt light yields of early fruit could be traced to this cause in some cases.

The practice of hardening greenhouse-grown tomato plants has been in general use in tomato growing areas for many years and has been considered to have a beneficial effect in preparing the soft greenhouse-or hotbed-grown plants for the harsher

environmental conditions in the field. The process consists of withholding water and exposing the plants to low temperatures in a coldframe before they are transferred to the field. In recent years this practice has been shown to have a detrimental effect on the ultimate progress of the tomato plants. Porter (40), Yeager (63), and Babb (4) found that hardening definitely reduced the early yield of marketable fruits and that this reduction resulted regardless of variety or of the time when the plants were set in the field. Brasher and Westover (7) concluded also that even a moderate hardening of tomato seedlings produced a stunting effect, did not make them better able to survive under early spring conditions, and resulted in lower early yields of fruit of lighter weight.

Object.

The need of developing an early tomato adapted particularly to Alberta conditions is urgent. Large fruit size is highly desirable in such a variety for commercial purposes as well as for the home garden. Of utmost importance in such a variety is earliness of maturity and this should be at least equal to that of the Farthest North variety. Moreover, the ability to ripen early should be accompanied by the ability to ripen under moderately adverse weather conditions.

Another purpose of these investigations has been to study the effects and value of commercial fertilizers in relation to their influence on the promotion of early fruit ripening in tomatoes

under Alberta conditions. There is no specific information available for Alberta gardeners concerning the most practical kind of fertilizer to use and how to apply it for best results. It is possible that a study of this kind has its limitations because the efficiency of fertilizers is largely dependent on soil moisture and soil type. That is, the results obtained under irrigation will be different from those under dryland conditions, and, also, fertilizers respond differently on a warm, sandy soil than on a cold, heavy soil. However, the results of fertilizer activity on tomato growth under a specific set of Alberta conditions may provide a lead in regard to the kind of fertilizer materials that could be used to advantage elsewhere in the province.

The depth at which tomato plants are set in the field has an important bearing on the time of ripening in tomatoes. The proper depth of planting has been a much debated problem. Gardeners in certain areas believe in deep planting while in other districts shallow planting is preferred. It was with the idea of obtaining data on the methods in use and therefrom to draw conclusions as to the best method of planting that this particular section of the thesis investigation was undertaken.

Green tomatoes can be ripened indoors after they have grown to their full size. However, difficulties are often experienced in obtaining satisfactory results. Factors affecting the ripening of green tomatoes indoors are principally temperature and humidity, although it is believed that colored paper wrapping

also has an influence. The investigation here reported was conducted with a view to ascertaining the optimum conditions for ripening green tomatoes in the home.

A final and important object of these investigations is to develop a tomato variety and certain cultural practices that will be applicable not only to the production of tomatoes in the home garden but as well to their production for commercial canning. The canning industry has made great progress in recent years in southern Alberta in the processing of different kinds of vegetables and the canners are hopeful of including tomatoes in the near future. In fact they have conducted tests with the most promising varieties but success has been elusive. Hence, an adapted variety together with improved cultural methods would be of value to one of Alberta's youngest and thriving industries.

PART I

PROMOTING EARLY MATURITY IN TOMATOES BY BREEDING

Breeding tomatoes for earliness, large fruit size and quality has been and still is, the primary purpose of a number of breeding projects in various institutions on the Canadian prairies and in the northern areas of the United States. Earliness and fruit size have been the deciding issues in regard to the successful production of tomatoes in the localities where the growing season is short. Thus far, Dr. A.F. Yeager, formerly of the North Dakota Agricultural Experiment Station, Fargo, has been most progressive in producing varieties combining the desired factors. However, the ideal prairie tomato has not yet been found. An attempt has been made in the tomato breeding work here reported to obtain a variety approaching the standard of this ideal type. The results have been very encouraging.

Literature Review

No literature review on this subject would be complete without specific reference to Dr. Yeager's work. Some of his results are indeed startling. For example, one of his introductions has made it possible to grow tomatoes as far north as Fort Vermilion and other areas not previously considered adapted to the outdoor culture of this crop. Yeager's methods of breeding were simple and

consisted principally of crossing standard varieties with desirable characteristics and selecting the progeny with the most promising features. However, Dr. Yeager evidently had a keen sense of detecting virtues of tomato varieties and applying these to a breeding program, according to some of the remarkable results he obtained in this work. The most outstanding has been his inter-specific cross. By combining one of his early, large-fruited varieties, Bison (<u>Lycopersicon esculentum</u>) with the currant tomato, (<u>Lycopersicon pimpinellifolium</u>), he obtained a variety, Farthest North, which appeared to be difficult to surpass in its extreme earliness. (The new tomato described in this report is equal to the Farthest North in earliness). The economic possibilities of the Farthest North are restricted by its small fruit size. Its plants are small, roughly 8 inches high and with 12- to 15- inch spread. It is extremely prolific in fruit production and will set as many as 150 - 200 fruits at one time. The object of the breeding work here reported was to retain the Farthest North plant type and size and to increase the size of its fruit so that it would have greater economic value.

<u>Types of tomatoes</u>.

It is probably not known generally that tomatoes are classified into two major groups based on type of plant growth, namely, indeterminate and determinate (self pruning). Each group is given distinctly different cultural treatment. The indeterminate type requires pruning and staking and its use, therefore, is

limited to special conditions in the home and market gardens. The determinate type requires no special care and accordingly is adapted to general field culture.

In order to acquaint the reader of this manuscript with the distinctions that are made between the two general groups of tomatoes so that a full appreciation of the selection of varieties used for breeding may be obtained, a description of these is given. Ordinary varieties of tomatoes, if grown under optimum conditions, are really perennial plants, that is, they continue growth indefinitely. Such varieties are classed as indeterminate tomatoes. Normally at every third leaf there is a blossom cluster. Tomatoes having this indeterminate type of plant set fruits relatively early and then continue to do so at intervals until frost comes in the fall, at which time there is usually a large number of blossoms being produced and small green tomatoes on the plant on which energy has been spent without the possibility of any usable product. Sometimes the home gardener pinches out the tip of the plant to prevent wasting this energy.

In sharp contrast to the indeterminate type of plant growth are the tomato varieties which have a determinate or self-pruning type of growth. These plants instead of setting the blossom cluster with three leaves between, produces blossom clusters often with only one leaf between them, and usually after growing a short distance a blossom cluster appears on the tip of the plant, terminating its growth. A plant such as this sets many more blossom clusters on the same length of vine as

one of the indeterminate type. Furthermore, it does not continue to blossom indefinitely but expends its energy in maturing the crop already set.

In the breeding project here reported the determinate type of plant was used exclusively.

Determinate Varieties of Tomatoes Classified

The following sub-classification of determinate tomatoes is based on observations under irrigated conditions in Southern Alberta. It helps to show the relationship of the parental varieties used in the experiment in regard to their plant characteristics and general field behaviour.

Class 1 - Extra early varieties - Plants dwarf, 8 - 10 inches high and 15 - 18 inch spread. Foliage very small and sparse. Numerous small fruits. Fruit ready July 26. Example - Farthest North.

Class 2 - Early varieties - Plants small, 12 inches high and 18 - 24 inch spread. Foliage small and light. Moderate number of medium-sized fruits. Fruits ready August 1. Example - Redskin.

Class 3 - Medium season varieties - Plants medium large, 15 inches high and 20 - 36 inch spread. Foliage medium large and medium dense. Moderate number of large- sized fruits. Fruits ready August 7 - 12. Examples - Bison and Polar Circle.

Class 4 - Late season varieties - (This group sometimes classed as intermediate between determinate and indeterminate types)

Plants large, 20 inches high and 36 - 45 inch spread. Foliage large and dense. Moderate number of large-sized fruits. Fruits ready September 1 - 10. Example - Pritchard.

Mode of Inheritance

A. Inheritance of earliness factor

Among the thirteen plant factors discovered in tomatoes by Price and Drinkard (41) in 1908 as giving the expected 3 : 1 Mendelian ratio, the type of growth of the tomato was included. Yeager (61) (64) and MacArthur (35) found later that indeterminate type is dominant to determinate and also that the progeny segregates according to the normal 3 : 1 expectations. Evidently the factors responsible for plant type are simply inherited. It is believed that the same type of inheritance occurs in crosses between classes 1 and 3 of the classification given above. These classes include the varieties Farthest North and Polar Circle, respectively.

In the breeding work here reported a cross was made between the Farthest North and Polar Circle. It was observed that most of the seedling progeny resembled the Polar Circle variety (the male parent). Since the object was to select seedlings of the Farthest North type it was necessary to produce a large population of seedlings. Yeager (61)(63) suggested the use of histological facts of the determinate tomato seedlings before the seedlings reach the second or true leaf stage. This helped materially in segregating

the bulk of the Polar Circle type of seedlings. A certain amount of experience is required to obtain efficiency in this work. However, the method suggested by Yeager saves much work by eliminating the Polar Circle type plants before they are transferred to the field and also before they have used up valuable greenhouse space in the early spring.

The F 1 progeny of crosses between distantly related varieties of tomatoes frequently exhibit hybrid vigor to a marked degree (1) (2) (13) (14). It is often expressed in the early maturity of the crop and care must be taken to distinguish this from standard early ripening. Wellington (56) obtained 33 out of 60 hybrids which gave an increase in early yield of fruit over the earliest parent. However, Hayes and Jones (14) discovered that not all F1 hybrids exhibited hybrid vigor but that it was usually evident or most pronounced in crosses of varieties which are quite distinct in one or several characteristics.

B. Inheritance of fruit size

In contrast to the simple inheritance of the earliness factor, the one responsible for fruit size is decidedly complex. Genetical studies have shown that fruit size is gene - transmitted; size as a character is usually complex and multifactorial (36). Many typical recessive mutant factors affecting size have been recognized and located in chromosomes (32). Some of these exert

their important size effects by modifying fruit shape or locule number or both (62); for example; the gene for fasciation (f) and those raising the locule number increase fruit size, probably by increasing the basic cell number, but at least two genes which are responsible for fruit elongation (ovate, o) tend to decrease its size. Other recessive genes with marked and distinguishing specific qualitative effects also have a general or physiological influence on size (33) (8); lutescent (l), a chlorophyll deficiency, slows down both plant and fruit growth and decreases the ultimate size of the fruit; tangerine (t) and possibly peach (p), on the other hand appear to enlarge the fruit, perhaps by acting on the cell expansion mechanism. These instances show that the several identified factors controlling size obviously do not necessarily or always lack dominance. Many are known to exhibit a typical dominant-recessive relationship. Some of the factors isolated are unequal (36) for they have been shown to affect size by varying amounts. Several of the genes determining size or number of cells are apparently distinct in nature and mode of influence, as they affect different processes and act at different times in the development of the individual (ontogeny). The histological analysis of fruit development, though still far from complete, already directs attention not only to one process but to many, such as rate and duration and localization of cell division.

Kaiser (22) studied the factors governing shape and size in the fruits of peppers and found that size is genetically determined by the interaction of a number of size genes, but is subject

to considerable modification by environmental factors. The ultimate appearance of the pepper is genetically determined by the interactions between factors governing (a) relative dimensional growth rates and (b) size of the fruit.

The influence of environmental factors further complicates a fruit size selection program with segregating progeny. For example, Gustafson and Houghtaling (12) found a definite relationship between tomato fruit size and the food supply of the plant. Reducing the number of fruits to one cluster per plant resulted in larger fruits than those normally produced. This may be correlated with the reduction in the number of tomato fruits set because of faulty pollination brought about by cool weather or by natural pruning through hailstorms.

C. The chromosome complex of tomatoes

The chromosome map of the tomato is still incomplete. MacArthur (32) (33) (34) (35) and Lindstrom (26) (27) have made possibly the greatest contributions to the present knowledge of this problem. Of some twenty genes that are known, the positions of sixteen have been located on ten of the twelve pairs of chromosomes. Six of the groups now contain two or more known genes.

Recently, Currence (9) discovered a relationship between the genes of the D_1POS region of the first chromosome and genes affecting earliness. However, the actual nature of the D and DP lines was not determined, although on the average they were 9 and 14 days earlier, respectively, than corresponding d and dp progenies.

MacArthur (35) reported that the genes (Tt), which control indeterminate and determinate growth habits, occur on the fourth chromosome.

D. The linkage problem

Evidence obtained by MacArthur (33) shows the possibility of linkage between possible genes for earliness and size. This appears to conflict with Larson's (24) findings who stated "that it is difficult, if not impossible, to combine characters such as extreme earliness, smooth fruit, and large fruit size in homozygous material". However, a recessive gene (l) for yellow-green foliage has been found to retard maturity about two weeks and to reduce fruit size 30 percent (33).

Method of Procedure

As a foundation for all plant breeding work a thorough knowledge of varieties is essential. Accordingly, a tomato variety test plot has been maintained in connection with this project. It has provided much information on general morphology and genetical behaviour of a long list of varieties. This information has been useful in choosing varieties with desirable characteristics and also in combining the varieties in such a way that the breeding work was greatly facilitated.

Varieties used

The object of this breeding program, as previously mentioned, has been to incorporate in a new tomato variety the factors affecting extreme earliness and large fruit size. The first of these, namely,

extreme earliness, is predominant in the Farthest North; hence this variety was chosen as one parent. For the second parent, a variety was selected in which comparative earliness was present as well as large fruit size. These characteristics were found in the Polar Circle variety.

In plant breeding it is often found that the desirable factor in a variety is recessive in nature. In such cases the variety with the recessive factor is generally used as the female parent because in this way the corresponding dominant factor is not in a position to exert a complete masking effect on the recessive one when the progeny of a cross begins to segregate. In the breeding project here reported the plant type of the Farthest North proved to be recessive and hence this variety was used as the female parent.

Hybridizing procedure

The method of breeding used in this work was similar in most respects to that in general use although certain details were changed and original ideas substituted to facilitate the work under local conditions.

The most vigorous plants were always selected for hybridizing. Usually the most convenient blossom buds were used and these were emasculated before they began to open. Emasculation consisted of removing the petals and stamens without injuring the pistil. In addition, a portion of the sepals were also removed so that the hybridized fruits could be easily recognized in case the identification tag was lost or obliterated. A glassine or transparent paper bag

Figure 1

Showing the comparative size of the plant and fruits of the F 6 hybrid, the method used to protect the flowers before and after pollination, and the identification tag.

was placed over the prepared blossom to protect it from foreign pollen and the effects of harsh environmental influences.

The blossoms were carefully pollinated within three days after emasculation. The pollen was obtained by jarring the cone-shaped tomato blossoms over a watchglass. The greatest amount of pollen was obtained from 9 a.m. until 2 p.m. during bright sunny weather. The transfer of the pollen was then made by lightly dipping the stigma of the emasculated blossom into the "heaps" of pollen dust on the watchglass. A cloth moistened with methyl alcohol was used to clean the watchglass after each pollination to prevent the transfer of undesirable pollen. Fresh pollen was used each time a new blossom was crossed. The glassine bag was replaced over the pollinated blossom and an identification tag attached. The tag bore the names of the varieties crossed namely, Farthest North x Polar Circle (the name of the female parent always preceded that of the male), the date when the cross was made, and the initials of the hybridist.

A number of crosses of the same varieties, 8 to 10 or more, were made at the beginning of the breeding program. The seed of the hybridized fruit of all the crosses was bulked. This seed was then planted in the greenhouse in the winter and the F 1 seedlings forced to maturity before the following spring. The seed of the F 1 seedlings also was bulked and the following F 2 seedlings planted in the field. As a rule the seedlings begin to segregate in the F 2 generation and the most desirable types can be selected. This permits

continuous selection up until the F 9 generation (an arbitrary limit) when the plants become pure or "fixed" for the desired type. However, the F 2 seedlings did not segregate as expected. In fact segregation did not occur even in the F 3 and F 4 generation seedlings. From all outward appearances the seedlings were identical with plants of the Polar Circle variety. However, the fact that the Farthest North had been used as the female parent and also because its plant type is so distinct from that of the Polar Circle, it was decided that the Polar Circle type was so dominant that it prevented the Farthest North type from segregating.

The fact that the progeny failed to segregate produced a major problem. The thought of discarding all the material was seriously entertained. However, a new idea occurred in regard to the possibility of ~~stimulating~~ encouraging segregation by artificial means. It was finally decided to try colchicine since the harsh effects of this drug on plants when used in strong concentrations had been noted and also studied in the literature.

Response to colchicine treatment

The colchicine was applied to a group of fifty F 3 seedlings in concentrations of .02, .2 and 2 percent solutions. An atomizer was used to treat the seedlings since it was found to produce a more misty spray than the usual type of sprayers. A fine spray is essential in treating tomato plants since all parts of the young seedlings are covered with a dense arrangement of hairs which

Figure 2

The individual plants of the segregating progeny are selfed to prevent cross pollination between "unfixed" relatives. Therefore, one blossom cluster of each plant is bagged and identified in a manner similar to that of the stake at the head of the row. Later when the plants are selected the seed fruits are saved only from those in the bag.

a coarse spray will not penetrate satisfactorily. The colchicine applications were made at regular intervals so that the growing tips were kept moist from 7 a.m. until 6 p.m. during four consecutive days. Some of the solution fell on the leaves below the growing shoots and it was the puckered appearance of these leaves that gave definite indication that the treatment had been effective. This occurred roughly six days after treatment began. The plants ceased growth almost immediately and remained stunted for approximately two weeks. Growth was finally resumed although quite slowly during the first week.

The treated seedlings were transferred to the field as soon as weather conditions permitted in the spring. Soon after the plants were re-established in the field variations were noted in the seedling plants. Six weeks after transplanting it was evident that definite segregation had taken place. Varying numbers of seedlings of the Polar Circle, Farthest North and intermediate plant types were found. It was also noted that the Farthest North type was in the minority, roughly one plant for every four or five of the other types.

Results

Among the Farthest North type of segregates, one plant was found which produced extremely early ripe fruits, at least three to four days earlier than the true Farthest North. In later generations, selections of this extremely early plant appeared to lose their extreme earliness and finally settled down to approxi-

mately the same season of ripening as that of the Farthest North. This fact suggested hybrid vigor which according to the literature review is frequently found in the F 1 progeny of distantly-related varieties.

A few seedlings of the colchicine-treated material were sent to Dr. A.W.S. Hunter of the Horticultural Division, Central Experimental Farm, Ottawa, to determine whether the chromosomes of the plants had been doubled by the colchicine. According to Dr. Hunter's report the chromosomes had not been doubled, which indicates that the effect of the colchicine had been primarily an ~~stimulatory~~ encouraging one. The fruit size of the treated Farthest North x Polar Circle seedlings was particularly desirable since it was practically three times as large as that of the Farthest North. However, it was noted that the size increased with the succeeding filial generations up to the F 6. This increase coincided with the decrease in earliness referred to above, suggesting a probable relationship between the factors responsible for both conditions.

An interesting comparison was obtained when a row of colchicine-treated Farthest North x Polar Circle hybrids were grown beside non-treated F 4 seedlings of the same cross. All the non-treated F 4 seedlings were of the Polar Circle type, whereas the treated hybrids were contrastingly of the Farthest North and extremely early maturing type. This demonstration proved without question that the use of colchicine played a definite part in the segregation process of this cross. Unfortunately, photographic evidence of this demonstration is not available.

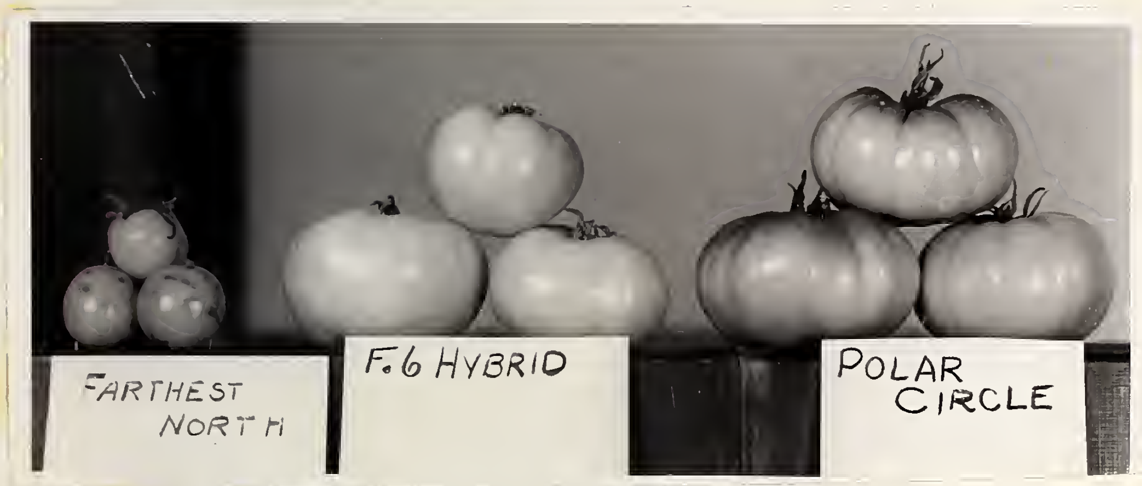

Figure 3

Comparison of the size of the fruits of the F 6 hybrid and those of its parents. The fruits here are full grown and unripe. Note the pale colour of the hybrid; this is the uniform fruit colour characteristic which guarantees a uniformly coloured ripe tomato.

Description of the new hybrid (Morphological)

1. Plant - Dwarf and compact in habit of growth, measuring 8 inches in height and with a 20-inch spread. Foliage relatively sparse and with oval shaped leaves.

2. Blossom - Blossom buds visible within 3 - 4 weeks from the time of seedling emergence. Plant elongation ceases after blossom buds are full grown.

3. Fruit - Develops rapidly after the blossoms are fertilized.

   (a) Skin - medium thick and brittle.

   (b) Color - when immature, pale green to whitish; when ripe, uniformly red over the entire fruit (no green shoulders).

   (c) Conformation - smooth with shallow corrugations at stem end; stem-end cracking absent.

   (d) Flesh - fine grained and slightly stringy with large juicy locules which contain numerous seeds.

   (e) Flavour - mild and pleasant.

   (f) Size - polar diameter 1.75 inches; equatorial diameter 2.50 inches.

   (g) Season - ready for use 75-80 days from time of seedling emergence.

   (h) Adaptability - the hybrid is still in the F 6 generation and hence it is somewhat too early to predict its adaptability to climatic conditions in southern Alberta. However, its performance in the cool, moist summer of 1941 was quite impressive. Yield records have not been kept

Figure 4

Plant size comparison of a typical F 6 seedling and its parents.

thus far because of the slight segregation of off-type fruits. When compared with the general appearance of average early varieties the hybrid performed remarkably well. It continued to ripen fruit consistently despite the cool and unfavourable conditions.

Economic possibilities of the hybrid

The possibilities of the Farthest North x Polar Circle hybrid appear very encouraging. Evidently its earliness and the relatively large size of the first fruits to ripen would be important factors in the successful commercial culture of tomatoes in southern Alberta. It is possible that the total yields may be lower than those of ordinary varieties but this difference can be accounted for by a closer spacing of the plants in the field. The small plant size permits a spacing of 12 - 15 inches between plants and 22 inches between rows. Ordinary varieties are usually planted $2\frac{1}{2}$ - 3 feet between plants and $3\frac{1}{2}$ feet between rows.

The shape of the hybrid fruit

The shape of the fruit of the Farthest North x Polar Circle seedlings is semi-globular, much like that of the Farthest North parent. In fact, the semi-globular shape has been evident in the progeny of all the filial generations. Not once did the flat, furrowed shape of the Polar Circle fruit appear in the hybrids. While it could be supposed that the semi-globular shape

is dominant to flat shape, the literature review indicates that inheritance of shape of fruit is governed by a complex arrangement of hereditary factors.

Color of the immature fruit

An interesting feature of the colchicine-treated hybrids is that the immature fruit is pale green to whitish in color. Before the colchicine treatment the hybrid plants had the usual dark-green fruits. This contrast in the color of the immature fruits of the treated and untreated hybrids was particularly outstanding in the demonstration plot referred to previously. The pale color of the immature fruit is very desirable because when such fruits ripen they color up uniformly over the entire tomato. On the other hand, dark-green-colored immature tomatoes ripen from the blossom end to the stem so that the shoulders are last to color up. Very often the shoulders do not color up satisfactorily and the fruits have an undesirable appearance.

PART II

PROMOTING EARLY MATURITY IN TOMATOES BY CERTAIN CULTURAL PRACTICES

A. Commercial Fertilizers

Commercial fertilizers play an important role in the promotion of early fruit maturity in crop plants. There are different kinds of commercial fertilizers, certain kinds of which when used in excess either alone or in an unbalanced combination will promote vegetative growth and delay or even inhibit sexual reproduction. On the other hand, there are fertilizers which retard vegetative growth and encourage early fruit formation and ripening. The object of this phase of the research work was to determine the proper fertilizer mixtures and the rate and method of application which would promote the largest yield of early fruit and not the kinds that promote early ripening, since this has been thoroughly worked out and reported in the literature.

Soils vary in their response to fertilizers. This fact has been amply demonstrated by experiments conducted on many different kinds of soil types throughout the world. Furthermore, the amount of moisture in the soil is also known to have a profound effect on fertilizer behaviour. The experiments here reported were conducted on heavy silt loam soil in the irrigated

area east of Lethbridge.

The commercial fertilizers used in the experiment were applied in liquid form to the growing plants both indoors and in the field. In this way the fertilizer elements become available much more quickly for plant use than if the soil moisture was to be depended upon to dissolve the dry fertilizer material. The use of rapid acting fertilizer solution was expected to supplement the rapid fruit ripening ability of the fertilizer elements.

Literature Review

Despite the fact that certain fertilizer elements encourage fruit maturity, their use must be supplemented by a knowledge of fundamental conditions such as plant characteristics, effect of environment, rate of application and rate of plant food absorption. Practically every kind of crop plant has its own particular "plant food" requirements and these must be supplied before any one or combination of elements can be used effectively in promoting early maturity. Moreover, fertilizers must be applied at a certain time and in a certain way before the proper utilization of the nutrients which they contain can take place. This requires a study of the tomato root system and its distribution in the soil.

Tomatoes thrive nicely on a soil containing liberal proportions of nitrogen and potassium and a fair quantity of phosphorous. The actual proportions required for optimum growth ~~have~~ are relatively generous if calculated on the basis that the tomato plant

producing a good crop contains
~~been calculated to be~~ 32.25, 11.30 and 56.45 percent of nitrogen, phosphorus and potassium, respectively (67). However, by increasing the amount of phosphorus, earliness may be increased according to Work in New York (59), Hepler and Kraybill in New Hampshire (15), Rosa in Missouri (44), Brown in Indiana (6), and Mack in Pennsylvania (30).

It is known that there is a close relationship between phosphorus in the plant and cell division, although it is difficult to determine the exact functions of phosphorus in the economy of even the simplest plants. It is present in the seeds of plants and, according to Lyon and Buckman (28), flowering and fruiting depend markedly on it. MacGillivray (37) found that increased maturation in the tomato is accompanied by progressive increases in the amount of phosphorus. Moreover, the tissues contain the highest percentage of phosphorus in the embryonic stage. The presence of an ample supply of phosphorus at such an early stage must have an important influence on the size of the fruit which will develop, since cell division, as previously mentioned, depends to a large extent on the phosphorus present. Mack et al (31) obtained evidence that dilute phosphoric acid or superphosphate solutions applied to the roots at transplanting time increased the early yield of tomatoes in comparison with water alone similarly applied.

Experiments have shown that the use of nitrogen alone or in a fertilizer mixture delays early fruit ripening in tomatoes

by encouraging excessive vegetative growth which remains green beyond the normal period of ripening (17) (23) (55). However, the use of nitrogèn in reasonable quantities appears essential. Sayre (49) obtained larger plants with greater yields as well as greater total yields by a judicious use of nitrogen in combination with phosphorus and potassium. Hester (18) also found that the nitrogen requirements of say 3,000 plants are about 3 pounds during the first month of growth, 27 during the second, and 70 pounds during the third.

The role of potassium in plant growth has much to do with the general tone and vigour of the plant. It is said to exert a balancing effect on both nitrogen and phosphorus and, consequently, it is especially important in a mixed fertilizer (28). Potassium is essential for starch formation and translocation and also is necessary in the development of chlorophyll.

Of the three fertilizer elements, nitrogen seems to have the quickest and most profound effect not only when present in excess of other constituents but also when used in moderate quantities. On the other hand, phosphorus is slow to react, probably because it becomes fixed rapidly in the soil on application. However, the activity of these elements also is somewhat dependent on environmental influences such as temperature and moisture. In a cold soil or one low in moisture, the bacteria needed in the ammonifying and nitrifying processes for producing available nitrogen and the acid forming bacteria which

ultimately promote the release of phosphoric acid, are slow to respond. Apparently, if it were possible to increase the moisture and temperature these processes would be accelerated.

Fertilizers are generally applied in dry, solid form to most crops growing in the field but it has been found that the plants fertilized in this way are comparatively sluggish, slow to start, and in certain cases may be harmful to the crop. However, certain experimenters have shown that by dissolving the fertilizers and applying them in solution as soon as the tomatoes are set in the field and also at intervals thereafter the results provide a definite margin of profit if the fertility level is not already adequate (18) (20) (21) (30) (39) (48) (49) (53) (54). The conclusions reached in regard to the results reported in the literature are: 1. The plants become established quicker and resume growth earlier and this results in earlier maturity. 2. Gains are particularly marked where plants are crowded in boxes before transplanting. Usually these have been starved somewhat. On the other hand, abundantly fertilized or widely spaced greenhouse-grown plants are not likely to show any greatly significant response from the starter solution applied in the field. The use of side-dressing with liquid fertilizers at intervals of two or three weeks is recommended for New Jersey (53).

Tiedjens (53) found that in the use of starter solutions (fertilizer solutions applied immediately after transplanting) certain properties are essential for success. In the first place,

it is necessary to have a slightly acid to neutral condition in the starter solution (pH 5.0 or somewhat higher). Superphosphate solutions alone are injurious since they generally have a pH 3.5. If these solutions are neutralized with ammonia or other alkaline material they may be used with satisfactory results. Secondly, the nutrient content of the starter solutions and its influence on the concentration of the soil solution around the seedling is important. Injurious results occur if the concentrations are too great. Ammonium phosphate, ammoniated superphosphate, and potassium sulphate are mentioned as sources of nutrients that cause very small increases in the concentration of the soil solution.

In commercial production, tomatoes are generally planted in the field with a transplanting machine which ejects $\frac{1}{2}$ - 1 pint of water around the roots as each plant is set in the soil. To speed up growth, 2 - 5 pounds of ammonium sulphate dissolved in 50 gallons of water is often used in the transplanting water. Baker (3) suggested the use of commercial phosphoric acid or mono-ammonium phosphate in the planting water instead of a nitrogenous fertilizer. This, he stated not only increased the yields of tomatoes but also caused them to ripen their fruit earlier than unfertilized plants. Sayre (50) reported that the use of hormones in the watering solutions tended to delay fruit maturity. But "3 cents worth of AmmoPhos., plus 17 cents worth of nitrate of potash per acre used in the planting water produced significant gains and increased the acre yield of early tomatoes by 1.44 tons and the

total yield by 1.85 tons" (50).

Dissolved fertilizers move only slight distances horizontally and to apply them outside of the root spread is ineffective (5) (38). Hence, a study of the feeding area of the tomato plant is essential for intelligent application of inorganic nutrients. According to Weaver and Bruner (57) a tomato plant produces a strong taproot with a few lateral roots if it is permitted to grow to maturity where the seed is sown. However, if the seedlings are transplanted at least once before they are set in their permanent location which is the usual practice, they develop well-branched laterals and a great feeding zone. Evidently transplanting is of considerable value in obtaining a dense root system so that when fertilizers are employed they may be fully utilized. Weaver and Bruner (57) also found that the most profuse root branching in tomatoes occurred 2 - 8 inches below the surface and that poor branching was found at the 8 - 10 inch depth. Furthermore, the branch roots extended 9 - 12 inches from the taproot, with a maximum of 2 feet in old plants. Since the application of fertilizers usually takes place when the plants are relatively young and also because the feeding area is where the root tips are found, it would seem that the best results would be obtained by locating the fertilizer material 6 - 12 inches from the taproot and about 8 inches deep. The use of fertilizer solutions would have considerable promise in carrying the nutrients to this zone. Localized placement of this kind has been found to be particularly effective in tomato

culture because it promotes more complete utilization of nutrients and ultimately earlier fruit ripening (5) (55).

Magistad and Truog (38) found that localized placement increased the osmotic pressure of the young plants and, in turn, lowered the freezing point of the plant 1 - 2 ^{o} C. This, they decided, is sufficient to prevent plants from being frozen by late spring frosts if the latter are not too severe. This would make early field planting possible and subsequently promote early fruit maturity.

In regard to the time of maximum nutrient absorption by tomatoes, Weaver and Bruner (57) and Boswell (5) state that early fruit maturity is increased by fertilizing early because the spring moisture helps to dissolve the fertilizer material. Furthermore, Hester (16), Lewis and Marmoy (25) and Du Pont (66) showed that in tomato plants the rate of nutrient uptake follows the rate of dry matter production fairly closely, being slow in the early stages of growth, attaining a maximum in June and July, and then declining. During the first month following transplanting, tomatoes made only 2 percent of their total growth and absorbed only 3 percent of the total plant food, which was about 2 percent of the plant food applied in the fertilizer. In the second month, the plants made 26 percent of their growth and absorbed approximately 30 percent of their food, or 25 percent of the total quantity of applied fertilizer. In the third and final month, the tomatoes made 72 percent of their growth and absorbed about two-thirds of the total plant food (61). Evidently the plants utilized most of the plant food applied in the fertilizer during the third month of growth.

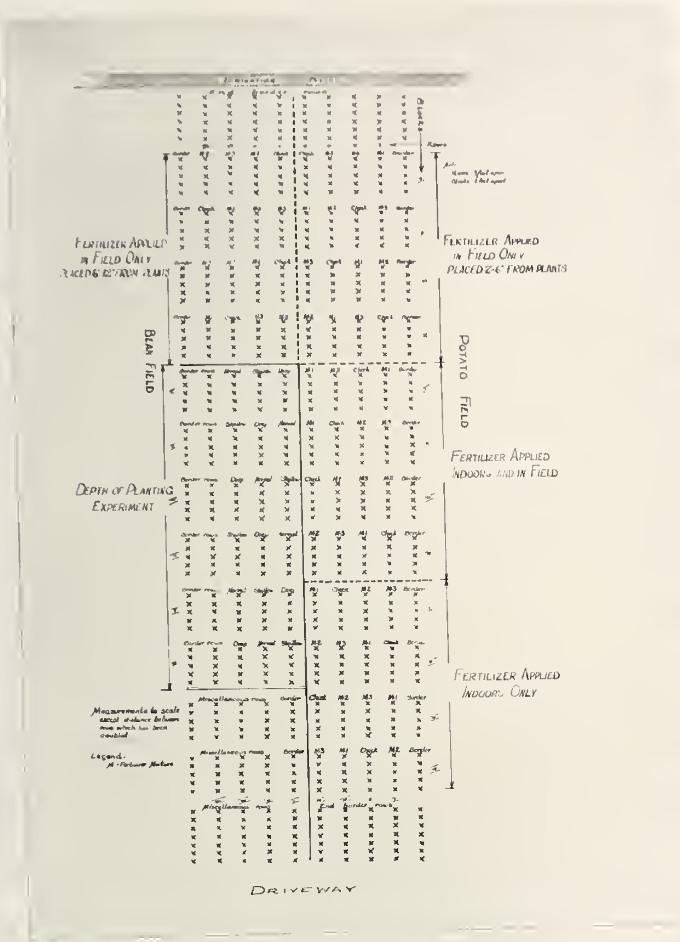

Figure 5

Field plan of fertilizer and
depth of planting experiments.

Furthermore, Hester (16) emphasized that it was particularly desirable to apply nutrients in two or three applications.

The kind of fertilizer to use in promoting early fruit maturity in tomatoes is obviously one in which phosphorus is predominant, according to the foregoing review. This supposition is supported by the results of a fertilizer experiment conducted with tomatoes in New York by Sayre (44). The most significant early yields were obtained by the use of a complete fertilizer high in phosphorus. A so-called complete fertilizer is one in which all three fertilizer elements, namely, nitrogen, phosphorus and potassium are represented.

Method of Procedure

The methods used in all the activities of this work were designed for rapid manipulation. The reason for this is obvious and is perhaps more clearly seen as the details of the method used are described. Suffice it to be stated that since the fertilizers were applied in their most rapidly available form (liquid), the plants in all the replicated plots would have to receive their portion at the same time or nearly so in order to keep the effect uniform. In practically all cases the methods employed were original or modifications of practices used by other workers so that efficiency could be obtained.

Variety used

The Bison variety was used and the seed was obtained

Figure 6

The commercial fertilizer test plot in mid-summer. Each stake represents a different treatment and precedes five tomato plants.

from the McFayden Seed Company, Winnipeg, Manitoba. Bison was selected for this experiment since it is relatively early in maturing its fruit, the fruits are large, and the plants are self-pruning (determinate type).

Fertilizer mixtures used

Mixtures of commercial fertilizers containing the three essential "plant food" elements (nitrogen - phosphorus - potassium were used. The form in which the essential elements were used varied somewhat according to the nature of the compound in which they were held. In Mixture 1, nitrogen was used in the forms of nitrate of soda and ammonium sulphate. The nitrate of soda was expected to produce available nitrogen immediately when put into solution. However, ammonium sulphate, was expected to release nitrogen somewhat more slowly than the nitrate of soda because the ammonium sulphate must first undergo a nitrifying process which is promoted by a particular kind of bacteria. Thus, by the use of these two compounds a quickly available and relatively constant supply of nitrogen was expected. The phosphorus element was supplied in Mixture 1 as triple superphosphate (43 percent available phosphorus) and as ammonium phosphate (11-48). The ammonium in the latter compound was expected not only to supplement the nitrogen supply but also to improve the physical condition of the fertilizer. Potassium was supplied in the form of potassium sulphate. Mixture 1 was made up to

Figure 7

The dark area at the base of the plant illustrates the limited space to which the fertilizer solution was applied in depressions 4 - 12 inches in diameter.

an 8 - 22 - 6 fertilizer; that is, it contained 8% nitrogen, 22% phosphorus, and 6% potassium. To make this the following were employed:

Triple super phosphate	(43%)	375 grams
Ammonium phosphate	11-48	125 grams
Sodium nitrate	(16%)	250 grams
Potassium sulphate	(50%)	125 grams
Ammonium sulphate	(20%)	125 grams
		1,000 grams

The ingredients of fertilizer Mixture No. 2 consisted of three compounds only, namely, triple superphosphate, ammonium sulphate and potassium sulphate. The mixture was made up to an 6 - 24 - 6 fertilizer having, according to the figures just mentioned, 6% nitrogen, 24% phosphorus, and 6% potassium. To make up this mixture only three compounds were used, namely:

Triple super phosphate	(43%)	567 grams
Ammonium sulphate	(20%)	305.5 grams
Potassium sulphate	(50%)	127.5 grams
		1,000 grams

Mixture No. 3 was a factory mixed fertilizer containing 9% nitrogen, 27% phosphorus, and 9% potassium.

Applying the fertilizer solutions

The fertilizer solutions were applied, in general, in three different ways. First, they were applied to the small tomato seedlings growing in boxes in the greenhouse. When applied in this way the fertilizer solutions were considered or referred to as "starter solutions". In certain areas in the United States the fertilizers solutions applied to tomato plants at transplant-

ing time in the field, are known as starter solutions. The second method of applying the fertilizer solution was to make the application after the plants were set in the field. Several field applications were made. A third method of application was to combine the first two and to use the solutions in the greenhouse and in the field.

The starter solution used in this experiment was made up at each application by mixing one-half cup of stock solution with one quart of water. The stock solution was prepared by dissolving one pound of the fertilizer mixture in a small quantity of hot water and then making it up to a gallon of cold water.

The tomato plants were all started in the greenhouse in "flats" or flat boxes measuring 15 x 21 x 3 inches. The plants which received the indoor treatment were permitted to become established in the flats before the fertilizer solutions were applied. After the applications were once begun all the moisture requirements of the plants were supplied by the fertilizer solutions only. The applications were made as often as the plants needed moisture. This amounted to five applications at ten or twelve day intervals.

In applying the fertilizer solutions in the field each plant was given one-half cupful of stock solution in one quart of water. This was done by pouring the solution into saucer-shaped depressions around each plant. Two different methods of field application were employed. One consisted of applying the solution

Figure 8

In the above illustration typical of the 12 - 24 inch diameter treatment, the comparative size of the saucer-shaped depression, into which the fertilizer solution had been poured, is shown.

in depressions 12 - 24 inches in diameter, the other in depressions 4 - 12 inches in diameter.

In all cases of fertilizer application in the field uniformity of application was emphasized. The untreated check plants were each given an amount of pure water equal in quantity to that of the fertilizer solutions applied to each treated plant. This was done to eliminate error, if any, from the effects that may be obtained by using liquids in the experiment. The field applications, four in number, were made at 12-day intervals beginning soon after the plants were set in the field.

<u>General plot treatment</u>

The plants were set in the field in units of five and each unit was replicated at random four times. At harvest time, the fruits of each unit were weighed and treated as an individual item.

The plot was located on irrigated land and water was applied three times during the growing season. This amount of irrigation water provided adequate soil moisture throughout the growing season and insured constant and normal plant growth. The soil was kept well cultivated and weed competition was not tolerated.

<u>Harvesting and recording yields</u>

Because of the large size of the plot much labor was

required to harvest and record the yield data and general notes of each plot. One man alone required about twenty hours to make a complete and thorough job each time. However, the work was organized in such a way that four men were able to do the same work in 4 - 5 hours. This method consisted of picking all the ripe tomatoes in the plot and placing them at the base of the stake representing each treatment. Then each lot was weighed and recorded in pounds and ounces and later these figures were converted to pounds and fractions thereof. For example, three pounds and five ounces were recorded in the field simply as 3 - 5 and later, when the yields were placed in tabular form, these were designated as 3.8 pounds. This practice permitted rapid and accurate recording in the field.

Experimental Results and Discussion

In analyzing the data of the fertilizer experiments it was somewhat difficult at first to arrive at a good criterion or index of earliness or early maturity of the different treatments under test. The earliest date at which ripe fruit could be harvested was thought at first to be a good criterion but later it was found to be unreliable. It was discovered that a number of factors, such as diseases, insects, and mechanical injury, often promoted premature ripening. Moreover, it was found that certain plants will sometimes begin production with one ripe fruit while others produce two and three fruits at the same time. Accordingly, the total production of ripe fruit was considered to be the most re-

liable and practical index of estimating early fruit maturity.

TABLE I

Fertilizer Solutions Applied in Greenhouse Only.

(Starter Solutions)

Treatment	Rep. No.	Position in plot R - B	Individual Harvest Weights lbs. - oz.	Total Yields lbs. - oz.	Total Yields lbs.
Mixture No. 1	1	1 : 3	0-4+ 1-6+ 2-10	4 - 4	4.25
	2	2 : 2	0-2+ 0-12+ 2-5+2-6	5 - 9	5.56
	3	3 : 4	0-10+0-5+2-8	3 - 7	3.43
	4	4 : 1	0-10+0-15+1-3+2-2	4 -14	4.87
			Average		4.53
Mixture No. 2	1	1 : 4	0-4+1-6+1-6+0-13+5-4	9 - 1	9.06
	2	2 : 1	0-7+0-14+1-0+6-0+1-2	9 - 7	9.43
	3	3 : 3	0-13+0-5+1-6+2-5	4 -13	4.81
	4	4 : 2	0-5+1-2+1-14	3 - 5	3.31
			Average		6.65
Mixture No. 3	1	1 : 1	0-3+2-3+2-6+4-10+6-8	15 -14	15.87
	2	2 : 3	0-6+4-12+1-10+2-8+5-0	14 - 4	14.25
	3	3 : 2	1-0+0-15+2-2+4-4	8 - 5	8.31
	4	4 : 4	0-3+2-8+0-9+2-13+2-0	8 - 1	8.06
			Average		11.62
Check	1	1 : 2	0-5+1-1+1-6+1-1+1-2	4 -15	4.93
	2	2 : 4	0-3+1-9+0-12+3-2+5-2	10 -12	10.75
	3	3 : 1	0-4+1-2+4-6+6-0+2-7	14 - 3	14.18
	4	4 : 3	0-9+1-7+1-2+0-8+3-8	7 - 2	7.12
			Average		9.24
			Check Average of Entire Experiment		12.87

Note:

R - B refers to row and block positions.

Rep. Replicate

The Yield Total represents the total yield of ripe fruits of five plants.

[illegible]

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

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TABLE II

Analysis of Variance of the Data for the *
Application of Fertilizer Solutions Indoors Only.

Variance due to	Sum of Squares	D.F.	Mean Square	F.	5% Point
Replicates	32.6603	3_n1	10.8868	2.19	5.41
Columns	59.3253	3_n1	19.7751	3.98	5.41
Blocks	7.0225	1_n1	7.0225	1.41	6.61
Treatments	112.0566	3_n1	37.3522	7.51	5.41
Error	24.8657	5	4.9731		
Total	235.9304	15			

Standard Error for the experiment 2.11
" " " " " in percent 26.18%
" " " " mean of one treatment 1.06
Significant Difference 3.17

Note: *
The calculations of the table of variance are given in the appendix at the end of the manuscript.

D.F. refers to the degrees of freedom.

F. refers to the F value.

Comments: Despite the fact that the standard error of this part of the fertilizer experiment is rather high it is still within the arbitrary working limit and hence the significant difference has some value. The cause of the rather high error is unknown, but it is assumed that this is due largely to the fact that tomato plots are generally exposed to a certain amount of pilfering, thus, certain plots are apt to show greater yields than others of the same treatment.

TABLE III

Fertilizer (Starter) Solutions Applied in the

Greenhouse and also in the Field

Treatment	Rep. No.	Position in plot R - B	Individual Harvest Weights lbs. - oz.	Total Yield lbs. - oz.	Total Yield lbs.
Mixture No. 1	1	1 : 1	0-14+0-1+3-0+4-2	8 - 1	8.06
	2	2 : 4	1-4+1-3+2-8+2-8-	7 - 7	7.43
	3	3 : 3	0-5+0-9+2-13+3-6	7 - 1	7.06
	4	4 : 2	0-5+1-3+2-0+2-1	5 - 9	5.83
			Average		7.09
Mixture No. 2	1	1 : 3	0-3+2-4+6-2+4-6	12 -15	12.93
	2	2 : 2	1-3+1-10+2-11+0-14	6 - 6	6.36
	3	3 : 1	1-0+0-8+1-2+3-14	6 - 8	6.55
	4	4 : 4	1-15+1-3+1-4	4 - 6	4.36
			Average		7.55
Mixture No. 3	1	1 : 2	0-11+3-9+0-3+3-7+4-9+4-4	16 -11	16.68
	2	2 : 3	0-6+4-6+2-8+2-2+8-12	18 - 2	18.12
	3	3 : 4	0-3+2-14+5-0+5-6	13 - 7	13.43
	4	4 : 1	4-9+4-11+2-14+0-15	13 - 1	13.06
			Average		15.32
Check	1	1 : 4	0-1+3-9+2-8+3-15+5-0	15 - 1	15.06
	2	2 : 1	0-5+1-0+3-2+9-0	13 - 7	13.43
	3	3 : 2	3-2+5-4+1-2+5-2	14- 10	14.62
	4	4 : 3	0-8+1-2+6-3+2-10+2-4	12 -11	12.70
			Average		13.95
			Check Average of Entire Experiment		12.87

Note:

R - B refers to row and block positions.

Rep. Replicate

The Yield Total refers to the total yield of ripe fruits of five plants.

[illegible]

[illegible]

[illegible]

[illegible]

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[illegible]

[illegible]

TABLE IV

Analysis of Variance of the Data for the

Application of Fertilizer (Starter) Solutions in the

Greenhouse and in the Field*

Variance due to	Sum of Squares	D.F.	Mean Square	F.	5% Point
Replicates	37.0653	3_n1	12.3551	17.71	5.41
Columns	17.2147	3_n1	5.7382	8.22	5.41
Blocks	8.2945	1_n1	8.2945	11.88	6.61
Treatments	218.2048	3_n1	72.7349	104.20	5.41
Error	3.4901	5	.6980		
Total	284.2694	15			

Standard Error for the experiment .... .84
" " " " " in percent........... 7.65%
" " " " Mean of one treatment .... .42
Significant Difference 1.26

Note:

* The calculations for the table of variance are given in the appendix at the end of the manuscript.

D.F. refers to the Degrees of Freedom.

F. refers to the F value.

Comments: In this particular section of the fertilizer experiment the standard error is comparatively low which indicates that the yields were fairly accurate and representative of the different treatments. Moreover, the fact that the error in this section is low supports the reason given for the large error in the previous section, namely, the application of fertilizer solutions in the greenhouse only. A glance at the field plan (Fig. 5) shows that the greenhouse plus field plot was in the centre of the field and hence not so accessible to pilferers as the others.

TABLE V

Fertilizer Solutions Applied in the Field Only

in Depressions Four to Twelve Inches in Diameter

Treatment	Rep. No.	Position in plot R - B	Individual Harvest Weights lbs. - oz.	Total Yields lbs.-oz.	Total Yields lbs.
Mixture No. 1	1	1 : 1	0-10+1-8+5-4+6-2+7-0-	20 - 8	20.50
	2	2 : 3	1-0+1-7+5-4+10-8	18 - 3	18.18
	3	3 : 4	0-3+1-9+2-4+3-3+5-12	12 -15	12.93
	4	4 : 2	1-11+1-4+3-12+8-10+8-2	23 - 7	23.43
			Average		18.76
Mixture No. 2	1	1 : 3	2-13+3-12+3-12+11-5+7-6	29 - 0	29.00
	2	2 : 1	0-12+5-4+4-14+3-6	14 - 4	14.25
	3	3 : 2	2-0+2-5+2-0+5-0+3-4	14 - 9	14.56
	4	4 : 4	1-1+0-11+2-4+8-0+6-7	18 - 7	18.43
			Average		19.06
Mixture No. 3	1	1 : 2	0-13+4-13+4-2+7-11+4-2	21 - 9	21.56
	2	2 : 4	0-4+1-0+1-5+0-13+3-14+10-8	17-12	17.75
	3	3 : 1	0-15+3-6+5-6+4-10+7-0	21 - 5	21.31
	4	4 : 3	0-3+4-1+4-8+3-4+5-6	17 - 6	17.36
			Average		19.49
Check	1	1 : 4	2-1+1-3+3-8+7-8+4-8	18 - 12	18.75
	2	2 : 2	1-15+1-9+3-6+7-14+6-12	21 - 8	21.50
	3	3 : 3	0-14+1-0+1-14+2-12	6 - 8	6.50
	4	4 : 1	1-0+5-4+7-2+4-3	17 - 9	17.56
			Average		16.08
			Check Average of Entire Experiment		12.87

Note:

R - B refers to row and block positions.

Rep Replicate

The Total Yields refer to the total yields of ripe fruits of five plants.

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[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]		[illegible]			

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TABLE VI

Analysis of Variance of the Data for the
Application of Fertilizer Solutions in the Field
in Depressions Four to Twelve
Inches in Diameter

Variance due to	Sum of Squares	D.F.	Mean Square	F.	5% Point
Columns	23.7079	3_n2	7.9026	.2558	9.12
Rows	152.8201	3_n1	50.9400	1.6492	6.59
Blocks	47.3000	1_n1	47.3000	1.5313	7.71
Treatments	28.5898	3_n2	9.5299	.3085	9.12
Error	123.5542	4	30.8886	1.0000	
Total	375.9720	14*			

Standard Error for the experiment 5.56
" " " " " in percent 30.30%
" " " " Mean of One Treatment 2.78
Significant Difference 8.34

Note:

* The Degrees of Freedom were reduced by one due to the correction for a missing value.

D.F. Degrees of Freedom.

F. refers to the F value.

Comments: The standard error in this section of the fertilizer experiment is comparatively high and almost beyond the arbitrary limit for the practicability of the data. The reason for this error is again obvious by consulting the cut of the field plan on page 36 which shows this plot at the end of the field exposed to those who do not always respect the exactness of experimental work.

TABLE VII

Fertilizer Solutions Applied in the Field Only

in Depressions Twelve to Twenty-four Inches in Diameter

Treatments	Rep. No.	Position in plot R - B	Individual Harvest Weights lbs. - oz.	Total Yields lbs.-oz	Total Yields lbs.
Mixture No. 1	1	6 : 3	2-3+5-14+5-14+8-14+7-12	30 - 9	30.56
	2	6 : 1	1-4+3-9+2-8+4-13+5-6	17 - 8	17.50
	3	7 : 2	0-5+1-8+1-5+8-0+3-14	15 - 0	15.00
	4	8 : 4	0-5+2-14+2-9+3-2+3-14	12 -12	12.75
			Average		18.95
Mixture No. 2	1	5 : 4	0-3+3-0+2-13+3-8+4-4	13 -12	13.75
	2	6 : 2	3-4+1-9+6-12+4-12	16 - 5	16.31
	3	7 : 3	0-12+3-0+2-13+13-0+5-12	25 - 5	25.31
	4	8 : 1	1-2+2-4+3-10+1-6+2-4	10 -10	10.62
			Average		16.50
Mixture No. 3	1	5 : 2	2-8+8-7+4-0	14 -15	14.93
	2	6 : 4	0-4+1-8+2-0+5-5+3-10	12 -11	12.68
	3	7 : 1	1-2+3-4+1-5+8-15+4-2	18 -12	18.75
	4	8 : 3	0-13+1-11+0-12+5-13+4-8	13 - 9	13.56
			Average		14.98
Check	1	5 : 1	0-14+2-4+0-5+3-8+4-4+4-8	15 -11	15.68
	2	5 : 3	0-8+1-13+1-9+2-10+3-0	9 - 8	9.50
	3	7 : 4	0-8+1-0+1-0+3-0+2-14	8 - 6	8.36
	4	8 : 2	2-4+3-7+7-10+7-2	20 - 7	20.43
			Average		13.49
			Check Average of Entire Experiment		12.87

Note:

R - B refers to row and block position.

Rep. Replicate

The Total Yields refer to the total yields of ripe fruits of five plants.

[illegible]

TABLE VIII

Analysis of Variance of the Data for the

Application of Fertilizer Solutions in the Field in Depressions

Twelve to Twenty-four Inches in Diameter

Variance due to	Sum of Squares	D.F.	Mean Square	F.	5% Point
Columns	125.7610	3n1	41.9203	.8773	5.41
Rows	59.7921	3n1	19.9307	.4171	5141
Blocks	2.9669	1n1	2.9669	.0621	6.61
Treatments	65.1649	3n1	21.7216	.4546	5.41
Error	238.9246	5	47.7849	1.0000	
Total	492.6095	15			

Standard Error for the experiment 6.91
" " " " " in percent 43.24%
" " " " Mean of One Treatment 3.45
Significant Difference 10.36

Note:

D.F. Degrees of Freedom.
F refers to the F value.

Comments: Unfortunately the standard error for this plot is exceptionally high, much more so than any of the previous ones. The reason for this error is also attributed to the causes mentioned in the previous Analysis of Variance for data in Table III. By consulting the cut of the field plan on page 36 this part of the fertilizer experiment will be seen to be located in a vulnerable position as far as pilfering is concerned.

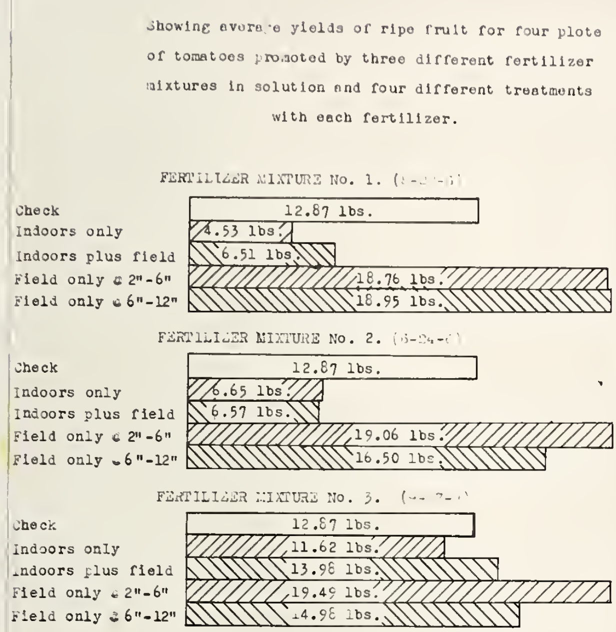

Figure 9

Results of the entire fertilizer experiment in bar graph form.

A comparison of the results of the fertilizer mixtures

Evidently the general reaction to the fertilizer mixtures, except for Mixture No. 3, which is a factory-mixed compound, was much the same. If the results of the indoor application of fertilizers are disregarded it is also evident that fertilizer Mixtures 1, 2 and 3 are quite effective in promoting the rapid ripening of tomatoes. In this regard, it was found that in most cases an approximate increase of 47.62 percent was obtained over the yields of the check plot.

A comparison of the results of the method of application

The striking fact of the entire fertilizer experiment is that negative results were obtained by the indoor use of Mixtures 1 and 2. In all cases the yields were consistently and also considerably lower than those of the check plots. The reason for this is quite apparent in view of the fact that at the time the plants were set in the field all the growth was very soft and tender, possibly the result of nitrogen activity. When the young plants were transferred to the field they received a severe check by wilting badly and it took four or five days for complete recovery. This delay in growth undoubtedly seriously deferred the early ripening of the fruit they were to produce later on. The plant response obtained in this particular case followed quite closely at first the initial theory that the nitrogen content

of the fertilizer mixtures would promote the production of large plants rapidly and that by the time the bulk of the nitrogen supply had been expended the phosphorus would slow down the growth and cause the reproductive functions of the plants to proceed. However, the check through transplanting had not been anticipated. It would seem evident that a repetition of these results would occur if the same procedure as was here employed should be used again. Moreover, it would seem doubtful if a satisfactory method of transplanting tomatoes treated with Mixtures 1 and 2 could be devised so that the plants would not be checked in growth.

Fertilizer Mixture No. 3 was practically similar in its "plant-food" content as Mixtures 1 and 2 but the results differed considerably. With the indoor treatment the results of Mixture 3 were practically the same as the check plots and only in one case did the plants fertilized in the field with Mixture 3 exceed in yield the indoor-treated and check-plot plants. The reason for these marked differences of the reactions of the fertilizer mixtures is not clear. However, it is quite likely that the method of mixing may have had an influence on the activity of the elements in the mixtures. Factory-mixed fertilizers are usually ground together after mixing it is possible that in this form fertilizer elements are incapable of acting independently as readily as those in hand-mixed fertilizers.

A comparison of the methods of field application

When applying fertilizers for an expressed purpose such as promoting early fruit maturity, it is obvious that the fertilizer must take effect as rapidly as possible. In order to facilitate this rapid action the fertilizers must be placed in close proximity to the root zone in which the heaviest feeding occurs. In this experiment two methods of field application were used in an effort to locate this zone. When the saucer-shaped depressions were made around the tomato plants some were made 4 - 12 inches in diameter and other 12 - 24 inches in diameter. In two cases out of three the results favored the 4 - 12 inch diameter depression. A slight difference in the results, favoring the 12 - 24 inch diameter depression, occurred when Mixture 3 was used. Despite the fact that the analysis of variance of the data shows considerable error between plots within a treatment and hence tends to indicate that the results are not entirely dependable, the fact that differences in yield are very marked, as shown on the bar graph (Figure 9), makes it difficult to believe that the 4 - 12 inch diameter treatment could be superseded by the other treatment, particularly with hand mixed fertilizers such as Mixtures 1 and 2.

PART II

PROMOTING EARLY MATURITY IN TOMATOES BY CERTAIN CULTURAL PRACTICES

B. Proper Depth of Planting

The proper depth of planting tomatoes in the field is possibly one of the most important cultural factors affecting the early production of ripe fruit. This fact is often overlooked by the tomato grower and the plants are usually set in the field simply according to the existing soil and weather conditions. However, the data obtained in this experiment definitely indicate that the best results can be obtained only with certain planting methods.

Tomatoes are generally transplanted to the field during the first or second week of June in southern Alberta. Usually the weather is relatively warm and dry at this time and this greatly influences the success of transplanting operations. On irrigated land the hazard is reduced by applying water but it may not always be available when needed most and, moreover, under dryland conditions the application of water is laborious and often precarious. In order to alleviate the distress that may be caused by a water shortage many growers and gardeners resort to deep

planting. By this method the roots of the tomato plant are placed in the soil moisture which is usually present deeper down. This practice encourages new roots to form all along the buried stem, since the tomato plant is capable of producing adventitious roots on any part of the plant. Accordingly, a large root system is produced which is believed to be beneficial for tomato production. In fact, Weaver and Bruner (57) reported that the plants which were set only as deeply as they had been growing previously in pots resulted in delayed fruit production, a smaller total yield and fewer and smaller fruits. Another advantage of deep planting is that the plant is held erect and thus injury due to strong winds may be reduced after transplanting and before the roots are re-established in the soil.

Deep planting may be beneficial to the indeterminate varieties of tomatoes but evidently this is not true of the determinate or self-pruning varieties which produce a much larger number of blossom clusters on the first foot of vine than the ordinary varieties. Hence, if this region of maximum flower cluster production is set below or just above the ground level much of the fruit will be lost or the yielding ability of the plant seriously affected.

In direct contrast to the deep planting method, tomato plants are sometimes set shallowly. Since tomatoes are a heat-loving type of crop it is believed that, by placing the root system as near as possible to the warm surface soil, the plant will grow rapidly and large. Furthermore, this system is sometimes modified so that the stem of the plant is buried near the soil surface and

as a result a large and extensive root system is produced. This large root system is thought to promote large plants and heavy yields. Obviously this method would require the use of water after the plants are set and hence it is adapted primarily to irrigated conditions.

Object of the Investigation

The purpose of this experiment was to determine the merits of deep and shallow planting of tomatoes and to compare these methods with the normal depth of planting. The normal depth is that at which the plants grow in boxes before they are set in the field. Thus far, no information supported by actual data is available for Alberta to substantiate the theoretical conclusions regarding deep and shallow planting.

Early ripening of tomatoes may well be expected to be retarded by deep planting in view of the fact that only a small part of the plant is left exposed above ground and this has to grow up and form a full-sized plant before fruit can be produced. Setting the plant deeply, therefore, obviously has a retarding effect on its progress despite the fact that the buried stem produces a large adventitious root system. It is possible that a large root system would be of considerable value in hastening plant growth but it would seem questionable whether this would compensate for the time lost by deep planting.

Figure 10

Deep planting, unquestionably, fortifies the newly-transplanted tomato plant against drought but it delays fruit maturity. The six inches above refers to the depth from the base of the stem while the ruler shows the depth of the basal roots.

In view of these facts an experiment with different depths of planting was considered not only advisable but also of great importance to growers who plant large quantities of tomatoes each year.

Method of Procedure

The variety used

The Abel tomato, a medium-late variety, was used for the experiment. It has been a relatively important variety with some growers and home gardeners in Alberta during the past five years. Abel is a semi-determinate type of tomato, producing plants with a relatively heavy foliage cover. The seed carried Dominion government seed registration No. V714.

Starting the plants

The tomato seedlings were started in flats in the usual way. The seed was sown on April 5 and the young seedlings were later transplanted into other boxes so as to provide more room for proper development. The plants were finally transferred to the field on June 8.

Arrangement and number of plants used in the field

Five plants were used for each treatment in each of six randomized blocks. The blocks were arranged according to the balanced block method of randomization.

Figure 11

The method of shallow planting is sometimes modified by shallowly burying the stem of the plant. An extensive root system is produced on the buried stem.

Setting the tomato plants in the field

Great care was used in placing the plants uniformly at the same depth and in the right position at planting time. The deeply-planted ones were so placed that approximately two inches of the plant tops were left above the soil surface. The plants that were set shallowly were placed in a shallow trench roughly $1\frac{1}{2}$ inches deep with the root end somewhat deeper because of the ball of soil. The plant top 3 inches from the end was turned up while the remainder of the stem was buried. This left 2 inches of the top exposed above ground as with the deeply-set plants. However, the difference in the placement of the deeply - and shallowly - buried plants will be noted. The check or normal planting consisted primarily of placing the plants at the same depth at which they stood in the indoor planted boxes.

Cultural practices

The plants were irrigated immediately after they were set in the field and two more applications were made later in the season as the soil became dry or as it became evident that they required water. The soil was cultivated often enough to keep it in good tilth and free of weeds. The soil, in general, was fertile and in good condition to promote normal growth. In all cultural practices the idea of uniformity for all treatments in the experiment was thoroughly followed.

Figure 12

Early ripening of tomatoes is obtained by the normal method of planting according to the results here reported.

Harvesting and recording yields

In this experiment the total weight of ripe fruit produced was used as the index of earliness promoted by the various treatments. As the fruits ripened they were picked and placed beside the identification stake representing each treatment. All of the randomized plots were harvested, weighed, and recorded in pounds and ounces. Later when analyzing the data these were converted to pounds and fractions thereof.

Results

The results of this experiment indicate that the depth at which tomato plants are set in the field has a very marked effect on the earliness of fruit ripening. Evidently the theoretical conclusions discussed previously have little practical application as far as the production of ripe fruit is concerned.

Observation and Discussion

The data presented by this experiment leave no doubt as to the best method to use in planting tomatoes. The normal planting method is decidedly superior to shallow and deep planting in the promotion of early fruit maturity. The data supporting these deductions are taken from plots planted at random and replicated six times.

The writer is aware of the fact that the results of this experiment are subject to the effects of environmental variations. It is possible that the data will vary somewhat from

Showing average yields of ripe fruit for six plots of tomatoes planted at different depths.

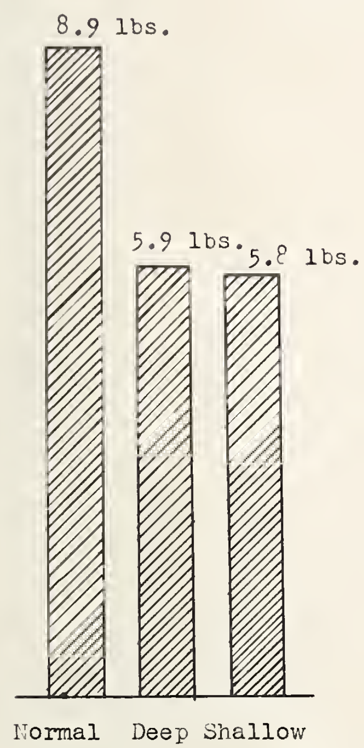

Figure 13

Deep and also shallow planting has a depressing effect on the yielding ability of tomatoes.

one season to another. Furthermore, the location of the experiment also will have a certain effect on the variableness of the data over a period of years. Despite these facts the results obtained from this experiment are so very contrasting that it would almost be possible to forecast the outcome of similar experiments conducted in the future.

Shallow and deep planting practices may have certain merits in regard to moisture relationships at planting time but according to the experiment the beneficial effects terminate at that time. It would seem that the only place for deep planting would be under dry land conditions where moisture is a limiting factor in the welfare of the tomato plant.

TABLE IX

Results of Different Depths of Planting

Tomatoes

Treatment	Rep. No.	Position in plot R - B	Individual Harvest Weights lbs. - oz.	Total Yields lbs.-oz	Total Yields lbs.
Normal Planting	1	7 : 1	0-7+0-2+1-3+1-2+6-0	8 - 14	8.87
	2	5 : 2	0-7+0-12+1-4+1-10+4-8	8 - 9	8.56
	3	6 : 3	0-5+0-15+0-14+0-7+6-0	8 - 9	8.56
	4	5 : 4	0-2+1-8+1-2+2-0+4-10	9 - 6	9.36
	5	7 : 5	0-4+1-3+2-14+4-14	9 - 3	9.18
	6	6 : 6	0-8+0-12+3-4+4-3	8 - 11	8.71
			Average		8.90
Shallow Planting	1	6 : 1	1-5+1-1+0-4+2-2+2-13	7 - 9	7.56
	2	7 : 2	0-8+1-4+0-12+0-15	3 - 7	3.43
	3	5 : 3	0-10+1-8+0-7+1-12+5-0	9 - 5	9.31
	4	7 : 4	0-9+1-7+0-7+1-2+2-4	5 - 13	5.81
	5	6 : 5	0-2+1-2+2-0	3 - 4	3.25
	6	5 : 6	0-6+1-5+1-5+0-12+2-2	5 - 14	5.87
			Average		5.87
Deep Planting	1	5 : 1	0-11+1-4+0-11+2-8+2-1	7 - 3	7.18
	2	6 : 2	0-6+1-5+0-1+0-9	2 - 5	2.31
	3	7 : 3	0-11+0-8+0-8+1-4+5-0	7 - 15	7.93
	4	6 : 4	0-9+0-4+0-2+1-12+5-12	8 - 7	8.43
	5	5 : 5	0-6+0-4+0-8+1-2+2-0	4 - 4	4.25
	6	7 : 6	1-1+0-14+1-9+2-2	5 - 10	5.62
			Average		5.95

Note:

The Total Yields refers to the total yield of ripe fruit per five plants

R - B refers to the block and position.

Rep. refers to the replicate number.

TABLE X

Analysis of Variance of the Data for the Different

Depths of Planting *

Variance due to	Sum of Squares	D.F.	Mean Square	F	5% Point
Treatments	35.0862	$2_{n}1$	17.5431	6.24	4.74
Paired Treatments	2.7945	$2_{n}2$	1.3973	.50	19.36
Replications	33.4195	$5_{n}1$	6.6839	2.38	3.97
Error	19.6833	7	2.8119		
Total	90.9835	16			

Standard Error for the experiment 1.68
" " " " " in percent 24.35%
" " " " Mean of One Treatment .... .69
Significant Difference 2.06

Note:

D.F. Degrees of Freedom
F. F value
* The calculations on which the results of this table are based are given in the appendix

Comments: While the standard error of the experiment is comparatively high, it is still within the arbitrary working limit and hence indicates the reliability of the data for making deductions in regard to the different treatments.

PART III

PROMOTING MATURITY IN TOMATOES BY GREEN RIPENING

Ripening full grown tomatoes indoors is an important means of producing ripe fruit long after frost has destroyed the field-grown vines and it is often possible to ripen large quantities of fruit as late as December. It is an important phase of commercial vegetable storage and it also serves as an important function in many farm homes.

Object of the Experiment

A number of methods of ripening full grown green tomatoes indoors are in use. Each of these is said to promote more rapid ripening than the other, although in no case has data been presented to show their relative merits. It was with the idea of ascertaining the efficiency of the methods in general use and also to select the most simple and effective procedure that this experiment was conducted.

Methods in use

Full grown, green tomatoes are generally selected for after ripening. They must be dry and relatively free of foreign material such as soil. They are placed in ordinary room temperature and in usual daylight exposure either

1. fully exposed and placed in single layers on tables,

shelves or on a floor, or

2. wrapped separately in paper which is either white, red or black. Each paper color has advocates. White paper produces a dispersed lighting effect which is believed by some to have particular advantages. Red color is thought by others to contribute to full and rapid coloring of the fruit. Black paper also has been used and it is believed by still others that the total darkness thus obtained is necessary for best results.

Literature Review

The ripening of green picked tomatoes under controlled conditions is an important practice in the commercial tomato growing areas of the southern states and while the methods employed are designed for special conditions they frequently apply in certain respects to a somewhat similar practice, namely, the ripening of green garden-grown tomatoes in the home. The optimum temperatures at which to hold the green fruit so that the ripening season indoors may be prolonged and also the best ripening temperature for rapid maturity, apply in both cases. Hence, a review of the research work conducted to date has an important bearing on the experiment here reported.

Holding green-mature tomatoes at low temperatures for a certain period to retard ripening and then transferring them to higher temperatures to accelerate ripening has given variable and in certain cases conflicting results. Diehl (10) exposed

green tomatoes to temperatures just above freezing for a 5-day period before placing in high temperatures without apparent injury. Another writer (68) concluded from his experience that tomatoes stored for 5 - 6 days at 1°C. will not ripen normally, and that injury will follow after storage at 10°C. for more than 12 - 15 days as indicated by failure to develop normal color and the rapid development of decay on removal from storage. Link (29) stated that the poor condition of tomatoes ripened in storage generally attributed to chilling is not due to the latter but to some other cause. This conclusion was based on observations made on thirty-three refrigerator carloads of tomatoes transported from Mexico to New Orleans. Ramsey (42) suggested that unsatisfactory ripening after storage may be due either to chilling, immature or poor quality fruit, or to rough handling in the ripening room. Rosa (43) (45) concluded that tomatoes generally ripen most favorably at a temperature of 25°C. while at 11°C. the ripening process is very slow and at 8°C and 4°C. ripening is almost inhibited. However, green-mature tomatoes ripened in air at 20 - 22°C. required from 8 to 20 days to develop sufficient color to be marketable; this long ripening period resulted in shrinkage, loss of flavor and loss by decay. Ripening was accelerated by adding to the air of the ripening room small amounts of ethylene or propylene gas; concentrations of 1:400 to 1:5000 were about equally effective. These gases caused the red pigment to develop rapidly and other ripening processes to be accelerated. Fruit

ripened in ethylene had a higher sugar content than that ripened in air.

Wright, et al (60) found that satisfactory ripening occurred after mature-green tomatoes had been exposed to 4.5°C. for 18 - 20 hours. In fact, exposure to a temperature as low as -7.5°C. for the same period encouraged normal ripening when subsequent storage occurred at a favorable temperature. The ripening of tomatoes stored at 4.5°C. for 11 - 15 days was delayed but took place normally. Chilling did not slow up or prevent ripening in fully mature-green tomatoes as noticeably as in less mature ones. The lowest temperature at which full ripening with good color and flavor developed was 13°C. At this temperature, the rate of ripening was comparatively slow, but the development of normal decay was also slow. For rapid ripening a temperature much higher than 21.5°C. is not desirable because of the rapid rate of decay. In all cases it is essential to keep the rooms moist to prevent shrivelling of the fruits. Mature-green tomatoes picked the evening before the first light field frost ripened in storage more rapidly and developed less decay than those picked the morning after the frost. In regard to the effect of light and darkness on the ripening of mature-green tomatoes it was found that the difference in results was not so marked in the rate of ripening as in the appearance of the fruit. When tomatoes were ripened in the dark the color was evenly distributed, whereas the light ripened fruits tended to be blotchy. Hoffman (19) reported that

green-mature tomatoes removed from the vine and ripened in a warm room had a higher vitamin C content if they were placed in diffused light than if they ripened in full sunlight or in total darkness, though total vitamin C content was not as high as in the fruit ripened on the vine.

West and Snyder (58) reported that the firmest green-ripened tomato fruits were obtained by wrapping in tissue paper. However, the loss of weight was least when the fruits were waxed. Normal loss of tomatoes during storage is due to respiration and evaporation. The difference in loss in weight between green and mature fruits ripened on the vine, according to Gustafson (11), is due to the fact that during normal growth the rate of respiration decreases, reaching a minimum at the given stages of maturity; it increases during ripening to a maximum when the fruits are orange to red in color, after which it again decreases. If the same changes in the rate of respiration occur during the artificial ripening of fruit, the green fruits which respire more rapidly than the ripe fruits, would be expected to lose more weight.

Sando (46) found that green-ripened tomatoes are often of inferior flavor and that this is due partly to immaturity of the fruit and partly to the practice of wrapping the fruit in paper, which excludes oxygen and so interferes with the ripening process. Because of the difficulty of picking green tomatoes which are mature enough to be of good quality, Sando suggested the use of "turning" fruit. He found that tomatoes picked on the turn could

be kept for 15 days at 10 - 13°C. and an additional 5 days at 24°C. "Turning" tomatoes ripened in storage developed about the same composition and flavor as those ripened on the plant.

Method of Procedure

The fruits used in this experiment were full-grown and entirely green. They were picked, just before frost threatened, from a group of plants of the Bison variety. They were thoroughly cleaned of dirt with a soft cloth.

Ten lots of tomatoes each consisting of forty-five fruits were prepared. These were then separated into two large groups each containing five lots. The large groups were placed in a temperature of 25°C. which was similar to that of a warm room in an average home, and the other group was placed in a temperature of 12°C. similar to that of an average farm outdoor root-cellar. The arrangement of the groups and the treatment of the different lots may be listed in the following manner:

Group 1

Placed in a temperature of 25°C. (a warm basement with window lighting)

Lot 1. (45 fruits) left unwrapped and exposed to light.

Lot 2. (45 fruits) left unwrapped and placed in total darkness.

Lot 3. (45 fruits) wrapped individually in white paper.

Lot 4. (45 fruits) wrapped individually in red paper.

Lot 5. (45 fruits) wrapped individually in black paper.

Group 2

Placed in a temperature of 12°C. (an ordinary root cellar with 200-watt lighting).

Lot 1. (45 fruits) left unwrapped and exposed to the environment.

Lot 2. (45 fruits) left unwrapped and placed in total darkness.

Lot 3. (45 fruits) wrapped individually in white paper.

Lot 4. (45 fruits) wrapped individually in red paper.

Lot 5. (45 fruits) wrapped individually in black paper.

The fruits in the above treatments were wrapped and placed in their respective positions at the same time. They were left in this way for a period of 13 days before a count was made on the number of fruits that had ripened.

Results

The results obtained from this experiment showed that in general the process of green ripening tomatoes is feasible and practicable. They also showed definitely the difference, if any, of the methods in use and also provided data in regard to the merits of these methods.

The uncovered or exposed fruits were the most rapid to color and ripen of any treatment used. This was true of both general groups. Moreover, the exposed fruits placed in the 25°C temperature ripened much more quickly than those kept at 12°C. Evidently a high temperature plays an important part in rapid green-ripening of tomatoes. Another factor in efficient green-ripening is that of light. The fruits left unwrapped in total darkness in a temperature of 21°C.

ripened faster than those placed unwrapped in a temperature of 9°C. However, it was observed that the fruits exposed to the higher temperature were soft (an undesirable feature) and many were badly shrivelled, whereas those exposed to a lower temperature were firm and full-bodied.

The paper in which the tomatoes was wrapped proved of little value in the promotion of rapid ripening. In fact, the data showed that in certain cases the paper wrapping retarded the ripening process, which is possibly due to the interference with normal respiration as suggested by Sando (46). Despite this disadvantage, the paper wrapping was beneficial in preventing the shrivelling of the tomatoes at 25°C. The red and white color of the paper wrapping did not noticeably affect the color of the tomatoes. However, the tomatoes wrapped in black paper were observed to be of a brighter red color when ripe or semi-ripe than the fruits ripened in the other treatments. This difference in color intensity was quite noticeable and occurred in the black paper wrapped fruits kept in both the high and low temperatures.

Observations

Most experiments conducted outdoors are subject to seasonal variation and to the variable effects of weather conditions. Accordingly, it is essential to conduct the same experiment over a period of years before reliable data can be obtained. However, experiments conducted under controlled conditions are not subject to these variations and hence the results obtained can be expected to

be identical or the same, in most cases, if the experiment is repeated. The variable factor in the green ripening experiment, namely, the stage of maturity of the green tomatoes, cannot be overlooked despite the fact that the work was conducted indoors. Some fruits may be about ready to turn red while others may not change color for a number of hours, although they may be full-grown when selected for the experiment. A condition such as this would be expected to have an influence on the final outcome of the experiment. Since it is impossible to select fruits at the same stage of maturity, this type of variation was disregarded. However, one fact is definite and that is, the most efficient method of after ripening will promote rapid ripening regardless of the stage of maturity of the full-grown fruits.

Discussion

The results of the experiment show that high temperatures are necessary in the promotion of rapid ripening of green tomatoes off the vine. This means that under ordinary home conditions the warm attic is to be preferred to the root cellar for this purpose. Covering or wrapping the tomatoes appears to have no special merits except that shrivelling is prevented, and color intensity is increased by the use of black paper. On the other hand, the high temperature (25°C.) exposure also causes the fruits to become soft and watery and therefore is none too desirable. In low temperatures (12°C.) ripening proceeds more slowly and the fruits remain firm. Apparently a temperature intermediate between the two would give the best results.

TABLE XI

Results of Green Ripening of Tomatoes

Group 1 Ripened for 13 days at 25°C. in subdued light.

Treatment	Ripe Fruits	Semi-ripe Fruits	Beginning to color	Green Fruits
Fruits exposed	32	6	3	4
Black paper wrapping	23	12	6	4
White paper wrapping	18	23	4	0
Red paper wrapping	16	22	4	3
Fruits in total darkness xx	6	5	15	19

x temperature somewhat lower, 21°C.

Note:
The fruits that were exposed during treatment were soft and badly shrivelled after the treatment. The fruits which were wrapped in paper were soft but only a few were shrivelled. The fruits kept in total darkness had some rotted and also shrivelled individuals.

Group 2 Ripened for 13 days at 12°C. in 200-watt light.

Treatment	Ripe Fruits	Semi-ripe Fruits	Beginning to color	Green Fruits
Fruits exposed	32	10	6	27
Black paper wrapping	1	6	15	22
White paper wrapping	2	4	13	26
Red paper wrapping x	2	7	12	24
Fruits in total darkness	0	1	1	43

x temperature somewhat lower 9°C.

Note:
The fruits of all the treatments in this group were quite firm and full bodied.

SUMMARY

The development of a new tomato variety, which under irrigated conditions and in weather generally considered unfavorable for tomatoes produces ripe fruit successfully, is here reported. It is an early ripening variety, produces fruits four or five times as large as those of the Farthest North variety (its maternal parent), and the plant characters of both are very much the same. The new tomato bears fruits with a deep red color, mild flavor, and fine quality. Furthermore, the immature fruits of the new tomato are pale-green to whitish in color, a condition which assures a uniform red color over the entire fruits as they ripen. This new tomato is now in the sixth filial generation and despite the fact that the arbitrary limit at which tomato hybrids become pure has been set at the ninth filial generation, its progeny appears to be already fairly well fixed for type. From outward appearances the commercial possibilities of this new tomato are quite promising.

The breeding work which produced the new tomato referred to above would probably not have been so successful if an original idea of using a chemical to stimulate segregation in the progeny had not been employed. The chemical, colchicine, played a positive part in view of the fact that without it the F3 and F4 generation seedlings of the cross which produced the new tomato, refused to "break up" or segregate into the different types.

Cultural methods such as the application of commercial fertilizers play a definite role in the early ripening of tomato fruits. The best results were obtained by applying a complete fertilizer (9-27-9) to the plants in solution in the field and in depressions 4 - 12 inches in diameter around the plants. Yields considerably greater than those of the check plots were obtained also from fertilizer mixtures 1 (8-22-6) and 2 (6-24-6). In all cases there was no advantage in applying fertilizers in solution to the young seedlings in the greenhouse as "starter solutions". In fact, this practice was decidedly deleterious because the tomato plants treated in this way were unable to withstand the shock of transplanting and as a result recovery was slow and fruit ripening delayed.

The depth of planting has a profound effect on the time of ripening tomatoes in the field. Deep planting insures a good start for the tomato seedlings, especially if the weather is hot and dry but materially delayed fruit ripening. On the other hand, shallow planting of the seedlings, so that the greater part of the stems are covered, was not conducive to early ripening. In both methods an extensive root system was produced along the buried stems of the plants but even with this advantage the results were negative when compared with those of the normal method of planting. The normal method consists of planting at the same level at which the plants grew in boxes in the greenhouse.

The results of the green ripening experiment of tomatoes demonstrated that immature tomatoes can be profitably ripened under ordinary farm conditions after fall frosts have killed the vines. The attic is preferred to the basement or the root cellar for this purpose since the results of the experiment showed that tomatoes ripen more readily at 20 - 22°C. than at lower temperatures. However, it is important that the humidity should be maintained to prevent shrivelling of the fruits. Wrapping tomatoes in paper reduces shrivelling but it appears to interfere with the normal transpiration processes of the fruits and thus retards ripening. Black paper produced fruits of a brighter red color than those which were exposed or wrapped in paper of other colors.

APPENDIX

On pages 47, 49, 51, 53 and 69 are given the tables for the analysis of variance for the data of the respective experiments. No attempt was made to show how the results were obtained because of the amount of space that would be required. However, the various steps in the calculations of these results are now given:

Analysis of Variance for the Data in Table I

Replicates					Total	Paired Total
Mix. No. 1	4.87	14.18	9.43	15.87	44.35	
Mix. No. 2	4.14	8.31	5.56	4.93	22.94	67.29
Check	7.12	4.81	14.25	4.25	30.43	
Mix. No. 3	8.06	3.43	10.75	9.06	31.30	61.73
Totals	24.19	30.73	39.99	34.11		
Paired Totals		54.92		74.10		
Grand Total					129.02	

Treatments					
Mix. No. 1	4.87	3.43	5.56	4.25	18.11
Mix. No. 2	4.14	4.81	9.43	9.06	27.44
Check	7.12	14.18	10.75	4.93	36.98
Mix. No. 3	8.06	8.31	14.25	15.87	46.49
Grand Total					129.02

General Mean 8.06
Correction Figure ......(Grand Total)^2 $\div$ Total No. of items = ... 1040.3850

a. Sum of Squares of Replications
1073.0453 - 1040.3850 = 32.6603

b. Sum of Squares of Columns
1099.7103 - 1040.3850 = 59.3253

c. Sum of Squares of Paired Replications
1063.3771 - 1040.3850 = 22.9921

d. Sum of Squares of Paired Columns
1042.3171 + 22.9921 = 1065.3092

e. Sum of Squares of Blocks
1072.3317 - 1065.3092 = 7.0225

f. Sum of Squares of Treatments
1152.4416 - 1040.3850 = 112.0566

g. Totals
1276.3154 - 1040.3850 = 235.9304

Analysis of Variance for Data in Table III

Replicates					Total	Paired Totals
Mix. No. 3	13.06	6.55	13.43	8.06	41.10	
Mix. No. 1	5.83	14.62	6.36	16.68	43.49	84.59
Check	12.70	7.06	18.12	12.93	50.81	
Mix. No. 2	4.36	13.43	7.43	15.06	40.28	91.09
Totals	35.95	41.66	45.34	52.73		
Paired Totals	......	77.61	....	98.07		
Grand Total	....	....	....	....	175.68	

Treatments					
Mix. No. 3	13.06	13.43	18.12	16.68	61.29
Mix. No. 1	5.83	7.06	7.43	8.06	28.38
Check	12.70	14.62	13.43	15.06	55.81
Mix. No. 2	4.36	6.55	6.36	12.93	30.20
Grand Total					175.68

General Mean 10.98
Correction Figure 1928.9664

a. Sum of Squares of Replications
1966.0317 - 1928.9664 = 37.0643

b. Sum of Squares of Columns
1946.1811 - 1928.9664 = 17.2147

c. Sum of Squares of Paired Replications
1955.1296 - 1928.9664 = 26.1632

d. Sum of Squares of Paired Columns
1931.6070 + 26.1632 = 1957.7702

e. Sum of Squares of Blocks
1966.0647 - 1957.7702 = 8.2945

f. Sum of Squares of Treatments
2147.1712 - 1928.9664 = 218.2048

g. Totals 2213.2358 - 1928.9664 = 284.2694

Analysis of Variance for Data in Table V

Replicates					Totals	Paired Totals
Check	17.56	21.31	14.25	20.50	73.62	
Mix. No. 1	23.43	14.56	21.50	21.56	81.05	154.67
Mix. No. 3	17.36	6.50	18.18	29.00	71.04	
Mix. No. 2	18.43	12.93	17.75	18.75	67.86	138.90
Totals	76.78	55.30	71.68	89.81		
Paired Totals		132.08		161.49		
Grand Total					293.57	

Treatments					Totals	Blocks
Check	17.56	6.50	21.50	18.75	64.31	76.86
Mix. No. 1	23.43	12.93	18.18	20.50	75.04	55.22
Mix. No. 3	17.36	21.31	17.75	21.56	77.98	77.81
Mix. No. 2	18.43	14.56	14.25	29.00	76.24	83.68
Total					293.57	

General Mean 18.34
Correction Figure 5386.4591

a. Sum of Squares of Replications
5539.2792 - 5386.4591 = 152.8201

b. Sum of Squares of Columns
5410.1670 - 5386.4591 = 23.7079

c. Sum of Squares of Paired Replications
5440.5183 - 5386.4591 = 54.0592

d. Sum of Squares of Paired Columns
5402.0024 + 54.0592 = 5456.0616

e. Sum of Squares of Blocks

5503.3616 - 5456.0616 = 47.3000

f. Sum of Squares of Treatments

5415.0489 - 5386.4591 = 28.5898

g. Totals

5762.4311 - 5386.4591 = 375.9720

Analysis of Variance for Data in Table VII

Replicates					Totals	Paired Totals
Mix. No. 2	10.62	18.75	17.50	15.68	62.55	
Check	20.43	15.00	16.31	14.93	66.67	129.22
Mix. No. 3	13.56	25.31	9.50	30.56	78.93	
Mix. No. 1	12.75	8.36	12.68	13.75	47.54	126.47
Totals	57.36	67.42	55.99	74.92		
Paired Totals		124.78		130.91		
Grand Total					255.69	

Treatments					Total	Blocks
Mix. No. 2	10.62	25.31	16.31	13.75	65.99	64.80
Check	20.43	8.36	9.50	15.68	53.97	59.98
Mix. No. 3	13.56	18.75	12.68	14.93	59.92	64.42
Mix. No. 1	12.75	15.00	17.50	30.56	75.81	66.49
Grand Total					255.69	

General Mean 15.98

Correction Figure 4086.0860

a. Sum of Squares of Replications .... 3 D.F.

4145.8781 - 4086.0860 = 59.7921

b. Sum of Squares of Columns .... 3 D.F.

4211.8470 - 4086.0860 = 125.7610

c. Sum of Squares of Paired Replications)

4088.4346 - 4086.0860 = 2.3486)

)....2.8213 (2 D.F.)

d. Sum of Squares of Paired Columns...... 1 D.F.)

4086.5587 - 4086.0860 = .4727)

e. Sum of Squares of Blocks .... 3 D.F.

4091.8742 - 4086.0860 = 5.7882 - 2.8213 = 2.9669 (1 D.F.)

f. Sum of Squares of Treatments .... 3 D.F.

4151.2509 - 4086.0860 = 65.1649

g. Totals .... 15 D.F.

4578.6955 - 4086.0860 = 492.6095

Analysis of Variance for Data in Table IX

(By Balanced Block)

							Totals
Deep	7.18	2.13	7.93	8.43	4.25	5.62	35.72
Normal	8.87	8.56	8.56	9.36	9.18	8.71	53.24
Shallow	7.56	3.43	9.31	5.81	3.25	5.87	35.23
Totals	23.61	14.30	25.80	23.60	16.68	20.20	124.19

General Mean 6.90
Correction Figure 856.8420

a. Sum of Squares of Replications
890.2615 - 856.8420 = 33.4195

b. Sum of Squares of Treatments
891.9282 - 856.8420 = 35.0862

c. Sum of Squares of Paired Treatments
859.6365 - 856.8420 = 2.7945

d. Sum of Squares of Totals
947.8255 - 856.8420 = 90.9835

General Comments

In the cases of all the tables, the Standard Error is equal to $\sqrt{\text{mean square of the error.}}$

Standard Error in percent is equal to $\frac{\text{Standard Error}}{\text{General Mean}} \times 100$

Standard Error of Mean of One Treatment is equal to

$\frac{\text{Standard Error}}{\sqrt{\text{of no. of replications}}}$.

Significant Difference is equal to 3 x Mean of One Variety

ACKNOWLEDGEMENTS

The author is indebted to Dr. J.S. Shoemaker, Professor of Horticulture, University of Alberta, for guidance and counsel in the course of this work. Sincere thanks, also, are due Dr. W.H. Fairfield, Superintendent, Dominion Experimental Station, Lethbridge, for his keen interest and the many suggestions that he made in this work. Further thanks are expressed to Mr. M.B. Davis, Dominion Horticulturist, Central Experimental Farm, Ottawa, for advice in outlining the experiments.

Sincere appreciation is also expressed for the assistance of a number of fellow workers, namely, J.R. Coyle and N. Bosomworth, in field plot details; J. Witrofsky, in statistical analysis of the experimental results; and J. Ringland, in the preparation of the manuscript.

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